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During Upper and Lower Body Exercise in Female Soldiers

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| 13. ABSTRACT (Maximum 200 words) The impact of smoking on exercise performance of female soldiers is of interest to the military. <u>Objectives</u> : To study in female soldiers: a) the chronic / acute effects of smoking on aerobic / anaerobic performance during lower / upper body exercise, b) the aerobic / anaerobic capacity for lower / upper body exercise and to correlate these values with the Army physical fitness test (APFT). <u>Methods</u> : Healthy female soldiers, 12 smokers, after abstaining from smoking (COHb < 2%) and after smoking (COHb: 6.5%), and 22 non-smokers were studied. Maximal aerobic power and cardiopulmonary variables were measured during lower / upper body exercise using an automated exercise system. Maximal anaerobic power during lower / upper body exercise was evaluated using the Wingate test. <u>Results and conclusions</u> : The chronic / acute effects of light to moderate smoking does not appear to impact the aerobic / anaerobic capacity for lower / upper body exercise; female soldiers have a normal aerobic and anaerobic capacity for upper and lower body exercise with an average level of fitness; they appear to be equally fit for aerobic and anaerobic exercise; no correlation was observed between the APFT and indices of aerobic / anaerobic capacity; maximal aerobic capacity was 60 % of men, 72 % when normalized for body weight. | | | | |
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FOREWORD

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FINAL REPORT

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INTRODUCTION

BACKGROUND

During exercise, muscle contraction requires energy (ATP), which is supplied by both the aerobic and anaerobic metabolism of nutrients.

Exercise lasting longer than 3-5 minutes uses energy provided by aerobic metabolism, while short bursts of high intensity exercise utilizes mainly anaerobic energy sources (34).

Advances in military technology have changed the nature of modern warfare. While previous wars were characterized by long marches and extended face to face battles where aerobic capacity was the main physical attributes of the soldier, the Persian Gulf war introduced "minimal personnel engagement with the enemy." When close combat was imminent, soldiers were transported to the scene. As result, anaerobic activities such as short sprints at high speed were also important physical attributes necessary to provide success and survival in these skirmishes.

Physical fitness is required for performance of all military duties. With the expanding role of women in the Army, which includes deployment of women to the field for training and deployment of female soldiers in an increasing number of combat roles (44), their physical readiness has become a crucial issue for the military.

Although several studies have evaluated exercise performance in male soldiers, glaring deficiencies exist in our knowledge of a broad spectrum of female soldier exercise performance issues.

Aerobic fitness levels for lower body exercise in Army soldiers have been previously reported. Most of these studies were performed predominantly in males with only a small number of females (33, 35, 41, 42)

To our knowledge, there have been no previous studies which have fully evaluated the level of fitness for upper body exercise in Army personnel, men or women. The importance of upper extremity work in the performance of military tasks and the anticipated differences between men and women have also not been thoroughly evaluated.

The ability to perform burst or exhaustive sprint type work, which is critical to modern warfare, has only recently received attention and then, only in male soldiers (21, 29). To the best of our knowledge, anaerobic power has never been evaluated in female army personnel.

Another area of interest to the military, especially as it relates to performance, is smoking. Available epidemiological data indicates that military personnel have a higher percentage of smokers than the civilian population. A Department of Defense survey indicates that 51% of military personnel smoke compared to 36% and 29% for males and females, respectively in the civilian population (6). Controversial results have been reported on the effect of smoking on human performance on male Army personnel (5, 10, 11, 17, 18). The results of these studies however are

tarnished by the poor characterization of the smoking history of the volunteers and for the lack of differentiation between the chronic and acute effects of smoking in human performance. Furthermore, we are not aware of any study that specifically addresses the effect of smoking on the exercise performance of the female soldier. This protocol will try to overcome some of the deficiencies of previous studies performed in male soldiers, which resulted in conflicting results about the effect of smoking in exercise

Differences between female military personnel and male soldiers are to be expected with respect to lower and upper extremity strength and work capabilities; this may also include anaerobic upper and lower extremity work. How these differences impact on specific military task performance between men and women remain unknown and could be addressed in subsequent task specific focused projects.

Data is needed to help more clearly define gender based performance standards. This work will provide an initial physiologic data base in female soldiers, not only on aerobic upper and lower extremity exercise, but also on anaerobic capacity for upper and lower body exercise. The physiologic data provided by this study will help in the analysis of current training regimens in order to enhance the performance of female soldiers in the field.

This work will provide a preliminary evaluation of the impact of smoking on exercise performance involving upper and lower body aerobic (endurance) and anaerobic (short sprints) exercise in female soldiers.

performance. The design of the protocol will allow the differentiation of the acute from of chronic effect of the smoking on the exercise performance.

PURPOSE OF THE PRESENT WORK

1- To determine the chronic and acute effects of smoking on aerobic and anaerobic performance during lower and upper body exercise.

2- To establish a comprehensive quantitative data base of aerobic (exercise longer than 5 minutes) and anaerobic (short bursts of high intensity exercise) levels of fitness for female army personnel for lower and upper body exercise.

3- To determine if female soldiers are more fit to perform aerobic or anaerobic exercise and upper or lower body exercise.

4- To correlate upper and lower body levels of fitness with Army physical fitness test results.

APPROACH

This is a prospective, controlled, parallel study, which involved healthy active duty female military personnel from Ft. Bliss, TX. Twenty-three smokers (after abstaining from smoking for 12 hours) and 12 non-smokers were studied on 2 different days. The smokers were re-tested on 2 more days after being prompted to smoke to achieve a COHb level of 6 to 8%.

These additional tests would allow for a comparison of chronic vs acute effects of cigarette smoking in the same individual. Maximal aerobic power during lower and upper body exercise was evaluated using a maximal incremental exercise test to volitional exhaustion on a cycle and arm crank ergometer, respectively. Metabolic and cardiopulmonary measurements were obtained using an automated exercise system. The maximal anaerobic power during lower and upper body exercise was measured using the Wingate "all-out" 30 sec test on a cycle and arm crank ergometer respectively.

BODY

PROTOCOL AND METHODS

This study was conducted in the Human Performance Laboratory of the William Beaumont Army Medical Center, El Paso TX at an altitude of 1270 m, mean PB 656 mm Hg and average temperature of 23° C.

Twenty-six non-smokers and 19 smokers, active duty, healthy Army female volunteers were recruited from Fort Bliss, Texas. Due to logistical reasons, only 23 non-smokers and 12 smokers were able to complete the study. All volunteers acknowledged voluntary participation in this study by giving informed written consent.

All the subjects completed a health questionnaire. Non-smokers and smokers after abstaining from smoking for 12 hours (to evaluate chronic effect of smoking) undertook 4 exercise tests on 2 days. Smokers had 4 more exercise tests on 2 additional days after being encouraged to smoke, to evaluate the acute effect of smoking. The order of the tests was randomly assigned. The duration of the study was of 2 days for non-smokers (4 tests) and 4 days for smokers (8 tests).

Volunteers who smoked less than 20 packs of cigarettes in a life time were considered non-smokers. Volunteers who were current smokers with at least 5 pack years smoking history were considered smokers. It was difficult to find smokers with a longer smoking history in this young group of soldiers.

Complete pulmonary function testing were measured following the ATS guidelines (2, 3). Spirometry and single breath diffusing capacity for carbon monoxide (DLCO) were determined in a pulmonary function system (Sensor Medics 2200). Lung volumes were determined in a variable pressure body plethysmograph (Gould 2800 Autobox). Reference values for spirometry (13), lung volumes (15) and DLCO (14) for whites, race corrected were used.

A venous blood sample was obtained before every exercise test for determination of baseline COHb and lactate. In the morning blood sample, a pregnancy test was also performed to document that the volunteer was not pregnant.

A carboxyhemoglobin (COHb) value of less than 2% was used as criteria for testing non-smokers and smokers during the nonsmoking day. A value between 6% to 8% was chosen as a criteria for testing smokers during the smoking day. For the non-smoking day, smokers were asked to refrain from smoking from the afternoon of the previous day. If the morning of the test COHb was more than 2%, 100% O₂ was administered for 40 minutes to washout half the CO from the blood. This procedure was only used on two occasions. For the smoking day, smokers were prompted to smoke normally the day before and to keep smoking before the tests a sufficient number of cigarettes to reach the expected blood levels of (COHb).

EXERCISE PROTOCOLS:

Day 1 - Morning

The maximal aerobic power for lower body exercise was determined using a maximal incremental exercise test to volitional exhaustion (approximately 10 min), on an electronically braked cycle ergometer. (Mijnhart Kem III). Metabolic and cardiopulmonary measurements were obtained in a breath by breath mode (8) using an automated system (Medical Graphics Corp. CPX) which integrates flow (Pneumotachometer Hans Rudolph No. 3800) and respiratory gases, measured with a mass spectrometer (Perkin-Elmer, MGA-1100). Heart rate and electrocardiogram were recorded in an electrocardiograph (Quinton 4000). At the end of the test, subjective evaluation of perceived exertion was performed using the Borg scale (9).

Five minutes post exercise a venous blood sample (1 ml) was obtained for determination of lactate (YSI 1500 Sport) and COHb (OSM 3 Hemoximeter, Radiometer).

Three hours were allowed for lunch and rest before the afternoon test.

Day 1 - Afternoon

The maximal aerobic power for upper body exercise was measured using an incremental arm crank exercise protocol to volitional exhaustion (approximately 8 min.). A modified electronically braked cycle ergometer was used (30). Metabolic and cardiopulmonary variables were also determined. At the end of the test, subjective evaluation of perceived exertion was performed using the Borg scale. Five minutes post exercise a

venous blood sample (1 ml) was obtained for determination of lactate and COHb.

Day 2 - Morning

The maximal anaerobic power for lower body exercise was determined utilizing the Wingate test (7). Subjects pedaled "all out" for 30 seconds on a mechanically braked cycle ergometer (Monark - 814 E) against a constant workload. The resistance for each volunteer was calculated as $0.09 \text{ kg} \times \text{body weight in kg}$. The mean resistance was $5.3 \pm 1.2 \text{ kg}$ for both groups. Peak anaerobic power, mean anaerobic power and percent fatigue (difference between peak power and the lowest power, expressed as a percentage of peak power) were measured. At the end of the test, subjective evaluation of perceived exertion was performed using the Borg scale. Five minutes post exercise a venous blood sample (1 ml) was obtained for determination of lactate and COHb. Three hours were allowed for lunch and rest before the afternoon test.

Day 2 - Afternoon

The maximal anaerobic power for upper body exercise was evaluated using a modified Wingate protocol for arm-crank ergometry. The resistance for each volunteer was calculated set at $0.048 \times \text{body weight in kg}$ (7). The mean resistance was $3.0 \pm 0.4 \text{ kg}$ for both groups. Peak anaerobic power, mean anaerobic power, and percent fatigue were determined. At the end of the test, subjective evaluation of perceived exertion was performed using the

Borg scale. Five minutes post exercise a venous blood sample (1 ml) was obtained for determination of lactate and COHb.

Day 3 and 4 for Smokers

Smokers were asked to repeat the 4 exercise tests on 2 more days, after smoking as usual and after reaching the expected range of COHb (6 to 8%) in the baseline venous blood.

Statistical Analysis: The SPSS for windows ver 7.0 statistical program was used for the analysis of the data, which will include descriptive statistics, ANOVA, Student *t* test, Pearson correlation coefficients, and linear regressions. A level of $p < 0.05$ was chosen for significance.

RESULTS

The anthropometric characteristics and smoking history of the studied volunteers grouped as non-smokers and smokers are presented in Table 1. Both groups are comparable in age, height and weight. The results of the most recent Army physical fitness test are reported in Table 2. No statistical differences were observed for any of the Army physical fitness tests between smokers and non-smokers. The pulmonary function tests, that included spirometry, lung volumes and diffusing capacity, were within the normal limits for both groups, no statistical differences were demonstrated between both groups except for FVC, which was higher in smokers (Table 3).

The chronic and acute effect of smoking on the aerobic performance of lower body exercise of female soldiers is presented in Table 4. No differences were observed between non-smokers and smokers during non smoking day for power, VO_2 , VO_2/kg , HR and LT; only VE was slightly lower on smokers during non-smoking day. A similar response was demonstrated for smokers between non-smoking and smoking day.

Similarly, in Table 5 the cardiopulmonary results of the maximal aerobic arm crank exercise for non-smokers and smokers during non-smoking and smoking days are presented. No statistically significant differences were observed between the non-smokers and smokers during the non-smoking day for any of the cardiopulmonary variables measured. The comparison in smokers, of non-smoking vs smoking day demonstrated a small but statistically significant difference in power (88 vs 80 watts respectively), no difference being observed for any of the other variables.

The results of the anaerobic capacity- evaluated by the Wingate test - for lower body exercise of non-smokers and smokers are shown in Table 6. No statistically significant differences were observed between the non-smoker and smoker (non smoking day) groups for any of the Wingate test variables measured. Similarly, no significant differences were observed for any of the variables measured in the smoker group between non-smoking and smoking days.

Likewise, the results of the anaerobic capacity, evaluated by the Wingate test, for upper body exercise of non-smokers and smokers are

presented in Table 7. No statistically significant differences were observed between the non-smoker and smoker (non smoking day) groups for any of the Wingate test variables measured. Similarly, no significant differences were observed for any of the variables measured in the smokers group between non-smoking and smoking days .

The relationships between maximal aerobic and anaerobic capacity, for leg and arm exercise are presented in Table 8. Although, the majority of the correlations were statistically significant, the r values were low and inconsistent.

The correlations between the several variables of the Army physical fitness test and the aerobic (VO_2 max) and anaerobic capacity (Wingate test) are shown in Table 9.

For reference purposes, maximal cardiopulmonary leg exercise responses were pooled for female non-smokers and smokers and then compared with historical data obtained in our laboratory in healthy young male soldiers (Table 10). The maximal power achieved by females for leg and arm exercise was approximately 65% of the maximal power achieved by males. The maximal VO_2 in absolute values attained by females was 60% and 65% of the values achieved by males for leg and arm exercise, respectively. However, when VO_2 was corrected for body weight and expressed as VO_2/kg the gender difference narrowed to 72% and 77% of the values achieved by males at maximal leg and arm exercise, respectively.

DISCUSSION

Despite the significant effort employed in recruiting volunteers, we were unable to reach our target number of smoking female soldiers. Possibly, this was related to the Fort Bliss antismoking campaigns, which make it unpopular for smokers to identify themselves as such. Also, for smokers the participation in the study required 4 days, interfering many times with their working or training schedules.

Although we recruited 26 non-smokers and 19 smokers, due to logistical problems (especially follow up appointments) we were able to complete all the tests in 22 non smokers and 12 smokers female Army personnel. Both groups have similar anthropometric characteristics (Table 1) and level of fitness evaluated by the Army physical fitness test (Table 2). According to the smoking history, the smoking group would be characterized as light to moderate smokers. Also, although not statistically different, the smokers were slightly older than the non-smokers.

Non-smokers and smokers had normal pulmonary function tests; with values that were within the normal range of the reference values (Table 3). No statistical differences in pulmonary function tests were observed between groups with the exception of FVC which was higher in smokers. Although within the normal range, the smoking group had lower FEV₁/FVC and lower FEF_{25-75%}, suggesting some early airway dysfunction.

Chronic Effect of Smoking on Aerobic Capacity.

The comparison of the maximal cardiopulmonary response to maximal incremental cycle ergometry exercise between non smokers and smokers during a non smoking day ($\text{COHb} < 2 \%$) can provide potentially helpful information about the chronic effect of smoking on the aerobic capacity of asymptomatic females (Table 4, Figure1). Tobacco smoke contains more than 4,000 components, many of them with harmful effects on the cardiopulmonary system (24). Smoke induces inflammation of the airways, increases bronchial hyper reactivity, produces alterations of the structure of the small airways and lung parenchyma with potential for airway obstruction(25). The airway obstruction decreases the ventilatory capacity thus contributing to the limitation of exercise performance. Smoking also induces gas exchange abnormalities due to reduction in diffusing capacity and ventilation perfusion inequalities which will result in hypoxemia and reduction in O_2 availability for muscular exercise (43). Multiple studies have convincingly demonstrated that cigarette smoking is the strongest determinant of chronic obstructive pulmonary disease (20). Apparently, the host factor plays an important role, since it is unclear why only 15 % of smokers develop COPD (19). It is also well established that smoking is a major factor in the development of heart disease. The two major forms of cardiovascular disease associated with smoking are coronary artery disease and peripheral vascular disease (32). It has also been postulated that small airway disease can be an early manifestation of pulmonary disease in

smokers; however all the attempts to convincingly demonstrate small airways disease through early detection has been unsuccessful. Also, it is unclear the duration of smoking which is necessary to induce pathological abnormalities sufficient to induce deterioration of the exercise capacity of the smoker. Smokers who already have developed COPD have exercise intolerance with significant reduction in aerobic capacity as compared to normals (27).

The comparability of the cardiopulmonary results between smokers and non-smokers during the non-smoking day, with the exception of minute ventilation -whose physiological significance is not clear -, would imply that in healthy individuals, 12 pack years of smoking does not significantly impact on the maximal leg exercise aerobic capacity. The effect of chronic, cigarette smoking on the aerobic capacity of asymptomatic smokers is extremely controversial. Although several investigators have shown consistent differences in exercise performance between smokers and non smokers (39, 17,18), the results of these studies are tarnished by poor characterization of the studied groups with respect to level of fitness, smoking histories, levels of COHb, resting pulmonary function tests, etc. The results of a large study carried out in Army male personnel (n: 685) by Daniels and collaborators(18) demonstrated a 5 % reduction in VO_2 max in smokers as compared to non-smokers. The same author in a previous study in Army male personnel (17), reported differences up to 10 % in VO_2 max between older (mean age: 44 yrs) smokers versus non-smokers, however no

differences in VO₂ max was detected between young (mean age: 22 yrs) smokers versus non-smokers; the authors concluded that smoking had little effect on aerobic fitness in a young, healthy and active population. Bahrke et al (5) did not observe difference in the 2-mile running time between 50 military personnel smokers and 97 non-smokers. Cooper (11) studied the effect of cigarette smoking on endurance performance in 419 young airmen. Significant differences in a 12 minute maximum running test were reported in smokers vs. non-smokers. As part of the same study, he compared the aerobic capacity (VO₂ max) between 25 non-smokers and 22 smokers during a maximal treadmill exercise test. No differences in VO₂ max between the 2 groups was observed. We are not aware of any study that has investigated the impact of smoking on the aerobic capacity of women. In summary, our results suggest that similar to men, light to moderate smoking does not have or have very little effect on the aerobic capacity of young, healthy and active women.

Similar results to leg exercise had been obtained for the maximal aerobic capacity during arm exercise of non-smokers and smokers during the non smoking day (Table 5, Figure 1). The lack of significant differences between non-smokers and smokers for the different cardiopulmonary variables measured, strengthen the finding that the chronic effect of mild to moderate smoking in young female soldiers does not appear to impact significantly on the aerobic capacity for lower and upper body exercise.

Acute Effect of Smoking on Aerobic Capacity.

The comparison of exercise results in smokers obtained during the non smoking day, in which they have abstained from smoking for at least 15 h and the level of COHb was less than 2%, with those of the smoking day in which smoking occurred as usual appears in Figure 1. In some cases smokers were encouraged to smoke on the smoking day in order to reach the minimum value of COHb of 6%; this allowed us to objectively determine the acute effect of smoking on healthy, young, female soldiers, physically active with light to moderate smoking habit. No statistically significant change was observed between the non smoking and smoking day for any of the cardiopulmonary variables measured at maximal incremental cycle ergometry exercise (Table 4). Likewise, no differences were observed between the smoking and non smoking day for the variables measured at maximal arm crank exercise, with the exception of power which was slightly lower (8 watts) during smoking day (Table 5). These results would imply that mild to moderate acute smoking does not appear to measurably impact the aerobic capacity for lower and upper body exercise of healthy, young females. Theoretically, acute smoking could negatively impact the exercise performance of the volunteers through several mechanisms. It is well appreciated, that from all the factors of acute smoking that can affect exercise performance, carbon monoxide and nicotine are maybe the most important. Increased levels of COHb reduce O₂ content of blood and decreases O₂ delivery to the muscles; CO also shift the O₂ dissociation curve

to the left thereby reducing O₂ unloading to the tissue. CO binds to myoglobin which may contribute to impaired O₂ delivery. Also CO impacts the function of respiratory enzymes and affects O₂ utilization (4, 40). Nicotine may also impact exercise performance by increasing heart rate and myocardial contractility and as a consequence, increase myocardial O₂ demand.

We are aware of only one paper, published in abstract form, that has studied the acute effect of smoking on exercise performance. Hirsch et al (23) performed cycle ergometry on 9 smokers on 2 different occasions, the first during the smoking day (mean COHb level of 6.6 %) and the second during the non-smoking day (COHb level of 1.8 %). Lower VO₂ max, anaerobic threshold and O₂ pulse, but higher heart rate and systolic blood pressure at maximal exercise was reported on the smoking day as compared to the non-smoking day. The differences in the results between this study and the present work could be explained by several factors, the first of which is the type of population studied. Hirsch does not mention the level of fitness of the men studied. The volunteers in our study were healthy, physically active females. Also, the differences between both studies are more apparent than real, because Hirsch reported a reduction in VO₂ max between smoking and non smoking days of 4 % and we reported 2 %. In addition, it should be considered that the reproducibility of VO₂ max is ± 5 %. In summary both studies demonstrate a minimal or no change at all in maximal aerobic capacity. This is probably due to the large reserve for cardiac and respiratory

function available in healthy young individuals. The reduction in O₂ content and O₂ unloading caused by smoking is probably compensated by increase in cardiac output and/or redistribution of blood flow to the exercising muscles, etc. It has been postulated that in a normal person when the level of COHb is less than 10 %, no significant decrement in exercise performance is detected.

Chronic Effect of Smoking on Anaerobic Capacity.

There is no readily apparent physiological reason for healthy asymptomatic smokers, with normal resting cardiopulmonary function tests, to have a reduced anaerobic capacity. It was no surprise that the results of the present study (Table 6 and 7) demonstrate no difference in any of the variables of the maximal anaerobic capacity (Wingate test), for leg and arm exercise, between non-smokers and smokers during non-smoking day (Figure 2). Our volunteers have a smoking history of only 12 pack years of smoking, which may not have been enough to induce measurable changes in the variables of the Wingate test.

Acute Effect of Smoking on Anaerobic Capacity.

From all the variables of the Wingate test measured during leg and arm exercise, maximal power during arm exercise was the only difference noted between non smoking and smoking days in smokers (Table 6 and 7). This small difference albeit statistically significant does not have physiological or clinical relevance. It would not have been unreasonable to expect differences between smoking and non-smoking days, because although

the Wingate test utilizes basically anaerobic metabolism, it has been postulated that 9 to 44 % of the energy requirements for this test comes from aerobic metabolism (26, 38). Since COHb through several mechanisms described above, decreases O₂ delivery and utilization, COHb could also impact in the Wingate test. However it appears that in normal individuals the functional reserve provide a sufficiently adequate level of oxygenation to the exercising muscles and, as such, a normal Wingate test. Since no significant differences were observed for the Wingate anaerobic test between smokers and non-smokers, we pooled the data to compare with the values reported by Maud and Shultz (31) in 69 young, physically active college women. The Wingate mean power measured in the present study (401 W) was slightly higher, although not statistically different to that (381 W) reported by Maud. The values were almost the same (6.7 vs 6.4 W/kg) when normalized for body weight

Level of Fitness of the Female Soldiers Studied.

Considering that practically no differences were observed between smokers and non smokers in aerobic and anaerobic capacity for upper and lower body exercise, we pooled all the data together to increase the statistical power of the sample size. The comparison of the cardiopulmonary variables measured at maximal cycle ergometry exercise with appropriate reference values for females (22) revealed a VO₂, VO₂/kg, and HR around 100 % of the predicted values. V_E was only 75 % of the reference value, indicating a normal breathing reserve. Also the power achieved was higher than the

predicted values. Using as a reference a widely used table from the American Heart Association (1) for level of fitness, the female soldiers studied can be characterized as having an average level of fitness. In a classic and largest study of aerobic capacity in the Army, Vogel and collaborators (41) measured the aerobic capacity of 1,514 men and 375 Army women. The VO_2/kg max reported by these authors on 212 females before basic training was 37.5 ml/kg/min. The value that was measured in the present work in 34 women was 32.7 ml/kg/min. It is known that VO_2 max measured on the treadmill is 7 to 11 % higher than that obtained on the cycle ergometer (45). Cycle ergometry was used in the present work and treadmill in Vogel's study. If the VO_2/kg measured in the present study is multiply by 10 % to correct for the difference between cycle ergometry and treadmill, the value would be 35.4 ml/kg/min very close to the value of 37.5 ml/kg/min reported by Vogel. Additionally, the discontinuous protocol used by Vogel vs. the continuous incremental of the present work, may also have contributed to the slightly larger VO_2 max. The data from this study reinforce the characterization of the level of fitness of the female soldiers as average.

Although the correlations, between indices of maximal aerobic and anaerobic capacity are statistically significant, the values are not as high as would be expected, and with inconsistencies noted, meaningful conclusions are difficult to make. The trend appears to be, that the women who have high aerobic capacity for leg exercise also have high aerobic capacity for arm exercise. Likewise, the women who have a high anaerobic capacity for leg

exercise also possess a high anaerobic capacity for arm exercise. However, it appears that the relationship between aerobic and anaerobic capacity is weak and inconsistent.

In general, the lack of correlation between the several variables of the Army physical fitness tests (APFT) and the aerobic and anaerobic capacity are surprising. Several authors (33, 36) have demonstrated a significant correlation between the 2 mile run time and VO_2 max for lower body exercise. Cooper (12) using a similar principle, demonstrated a good correlation between the distance covered in a 12 min run and VO_2 max. Knapik (28) in a review article about the Army physical fitness test presents a summary table of several studies related to running performance and VO_2 max. Although the majority of studies showed a good correlation there were 3 studies with correlation lower than - 0.5. It is important to mention that the study with the worst correlations was performed in young college women (16), the studied population and results are similar to the present work. We do not believe that that the discrepancies with previous papers is due to differences in the gender of the volunteers studied, but rather, are at least partially due to the narrow range in the values of the APFT and VO_2 max. Another very likely explanation is that during the APFT the female soldiers do not push themselves to the maximum of their capabilities, but rather exert themselves to achieve the minimum requirements to pass the 2 mile run portion of the APFT.

The comparison of the cardiopulmonary response to maximal aerobic exercise for legs (Table 10, Figure 3) between the pooled data of the female soldiers studied and the data obtained in our laboratory in a previous study (30) in male soldiers using the same equipment and methodology demonstrated that the maximal aerobic power ($\text{VO}_2 \text{ max}$) of women was 60 % of men when expressed in absolute values, and when normalized for body weight women were 72 % from men. The difference in minute ventilation was proportional to the difference in VO_2 . The maximal heart rate was similar for men and women as has been previously described (37). Similar to the present work, Vogel and collaborators (41) found that women soldiers achieved 61 % of the $\text{VO}_2 \text{ max}$ achieved by male soldiers when expressed in absolute values and 73 % when normalized for body weight.

A similar comparison of the cardiopulmonary response to maximal aerobic exercise for arms (Table 11, Figure 3) between the female soldiers and the data obtained in our laboratory in a previous study in male soldiers (30) using the same equipment and methodology demonstrated that the maximal aerobic power for arms ($\text{VO}_2 \text{ max}$) of women was 65 % of men when expressed in absolute values and when normalized for body weight women were 77 % from men. The lower values in minute ventilation in females were proportional to the lower values in $\text{VO}_2 \text{ max}$. As in upper body exercise, the maximal heart rate was similar between male and females soldiers.

CONCLUSIONS

1. The chronic effect of light to moderate smoking in young, healthy, physically active, females, does not appear to impact the aerobic capacity for lower and upper body exercise.
2. The acute effect of moderate smoking, mainly due to high levels of nicotine and COHb (6 %) does not negatively impact the aerobic capacity for lower and upper body exercise of young, healthy, physically active women.
3. The chronic and acute effect of smoking does not appear to impact the anaerobic capacity for lower and upper body exercise of young, healthy, physically active women.
4. The cardiopulmonary responses to maximal aerobic exercise of young female soldiers were approximately 100 % of the reference values for matched sex, age, height, and weight.
5. The level of fitness for aerobic exercise of female soldiers can be characterized as average which is comparable to other reported studies.
6. The anaerobic capacity of the female soldiers was comparable to the values reported in the literature in normal young physically active females.
7. The female soldiers appears to be equally fit to perform aerobic and anaerobic exercise.

8. It appears that indices of maximal aerobic capacity cannot reliably predict anaerobic capacity.
9. No correlation was observed between the indices of the Army physical fitness test and the maximum values of aerobic and anaerobic capacity for upper and lower body exercise.
10. The maximal aerobic power ($\text{VO}_2 \text{ max}$) of women was 60 % of men when expressed in absolute values, however when normalized for body weight it was 72 % of men, consistent with another studies.
11. The maximal aerobic capacity of the female soldiers and the difference from male soldiers does not appear to have changed since 1986 (41).

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APPENDIX

Table 1
Anthropometric Characteristics and Smoking History of Female
Volunteers (mean \pm SD)

| | Non-Smokers (n = 22) | Smokers (n = 12) | Total (n = 34) |
|------------------|--------------------------------|----------------------------|--------------------------|
| Age (yrs) | 26 \pm 6 | 30 \pm 7 | 27 \pm 6 |
| Height (cm) | 162.3 \pm 10 | 163.9 \pm 5 | 162.8 \pm 9 |
| Weight (kg) | 60.1 \pm 9 | 59.3 \pm 7 | 59.8 \pm 8 |
| Smoking (pk yrs) | 0.0 \pm 0 | 12 \pm 8 | |

* $p \leq 0.05$, 2 tailed, independent *t*-test

Table 2**Army Physical Fitness Test Results (mean \pm SD)**

| | <u>Non-Smokers</u> | <u>Smokers</u> | <u>Total Group</u> |
|-------------|---------------------------|-----------------------|---------------------------|
| | (n = 22) | (n = 12) | (n = 34) |
| Push Ups | 39 \pm 19 | 37 \pm 7 | 38 \pm 17 |
| Sit Ups | 64 \pm 17 | 65 \pm 18 | 64 \pm 16 |
| Total Score | 247 \pm 40 | 250 \pm 30 | 248 \pm 37 |
| 2' Run Time | 17:31 \pm 2:05 | 17:58 \pm 2:08 | 17:01 \pm 2:03 |

* $p \leq 0.05$, 2 tailed, independent *t*-test

Table 3
Pulmonary Function Tests[†] (mean ± SD)

| | Non-Smokers | | Smokers | | Total Group | |
|---------------------------|-------------|--------|--------------|--------|-------------|--------|
| | (n = 20) | % Pred | (n = 10) | % Pred | (n = 30) | % Pred |
| FVC (L) | 3.58 ± 0.57 | 103% | 4.01 ± 0.13* | 108% | 3.72 ± 0.55 | 105% |
| FEV ₁ (L) | 2.99 ± 0.41 | 100% | 3.16 ± 0.41 | 98% | 3.05 ± 0.41 | 99% |
| FEV ₁ /FVC (%) | 83% ± 7.6% | | 79% ± 6.4% | | 84% ± 7.0% | |
| FEF ₂₅₋₇₅ | 3.33 ± 0.57 | 93% | 3.01 ± 0.86 | 80% | 3.22 ± 0.68 | 89% |
| MVV (L) | 128 ± 19 | | 126 ± 20 | | 127 ± 19 | |
| TLC | 5.07 ± 1.07 | 111% | 5.18 ± 0.78 | 105% | 5.11 ± 1.0 | 109% |
| RV | 1.50 ± 0.62 | 123% | 1.84 ± 1.5 | 103% | 1.62 ± 1.0 | 117% |
| D _L CO | 23.9 ± 3.6 | 90% | 24.2 ± 3.0 | 84% | 24.0 ± 3.4 | 88% |

* $p \leq 0.05$, 2 tailed, independent *t*-test

[†] Predicted values are race corrected

Table 4
Cardiopulmonary Variables at Maximal Incremental Leg
Exercise Test (mean \pm SD)

| | Non-Smokers (n = 22) | Smokers Non-Smoking (n = 11) | Smokers Smoking (n = 12) | Total** Group (n = 33) |
|-----------------------------|--------------------------------|--|--|--------------------------------------|
| COHb (pre) | 1.1 \pm 0.4 | 1.4 \pm 0.5 | 6.5 \pm 1.2 [†] | 1.2 \pm 0.5 |
| Power (watts) | 166 \pm 23 | 162 \pm 11 | 163 \pm 20 | 164 \pm 20 |
| % Pred Power | 149% | 146% | 147% | 148% |
| VO ₂ (L/min) | 1.96 \pm 0.34 | 1.92 \pm 0.16 | 1.88 \pm 0.25 | 1.95 \pm 0.28 |
| % Pred VO ₂ | 108% | 105% | 103% | 107% |
| VO ₂ (ml/kg/min) | 32.9 \pm 6.1 | 32.3 \pm 3.4 | 31.2 \pm 4.9 | 32.7 \pm 5.3 |
| V _E (L/min) | 94 \pm 17 | 83 \pm 7.4 [*] | 89 \pm 20 | 90 \pm 16 |
| % Pred V _E | 78% | 68% | 73% | 75% |
| HR | 180 \pm 12 | 182 \pm 7 | 181 \pm 13 | 181 \pm 11 |
| % Pred HR | 93% | 95% | 94% | 94% |
| LT | 8.3 \pm 1.5 | 8.7 \pm 2.2 | 7.8 \pm 1.8 | 8.4 \pm 1.7 |

* p \leq 0.05 , 2 tailed, independent *t*-test, Non-smokers vs Smokers (non-smoking days)

[†] p \leq 0.05 , 2 tailed, independent *t*-test, Smokers (non-smoking) vs Smokers (smoking) Tests

** For reference only, no stats - All non-smoking tests

Table 5
Cardiopulmonary Variables at maximal Incremental Arm
Crank Exercise Test (mean \pm SD)

| | Non-Smokers (n = 22) | Smokers Non-Smoking (n = 9) | Smokers Smoking (n = 11) | Total Group (n = 31) |
|-----------------------------|--------------------------------|---|--|------------------------------------|
| COHb (pre) | 1.1 \pm 0.6 | 1.5 \pm 0.6 | 6.9 \pm 1.3 [†] | 1.2 \pm 0.6 |
| Power (watts) | 88 \pm 14 | 88 \pm 13 | 80 \pm 10 [†] | 87 \pm 14 |
| VO ₂ (L/min) | 1.41 \pm 0.24 | 1.36 \pm 0.24 | 1.30 \pm 0.20 | 1.40 \pm 0.24 |
| VO ₂ (ml/kg/min) | 23.6 \pm 4.5 | 21.3 \pm 3.7 | 21.2 \pm 3.4 | 23.5 \pm 4.4 |
| V _E (L/min) | 68 \pm 13 | 67 \pm 13 | 66 \pm 12 | 67 \pm 13 |
| HR | 173 \pm 15 | 180 \pm 10 | 178 \pm 13 | 175 \pm 14 |
| LT | 6.4 \pm 1.7 | 7.3 \pm 1.7 | 6.6 \pm 1.3 | 6.7 \pm 1.7 |

* p \leq 0.05 , 2 tailed, independent *t*-test, Non-smokers vs Smokers (non-smoking days)

[†] p \leq 0.05 , 2 tailed, independent *t*-test, Smokers (non-smoking) vs Smokers (smoking) Tests

** For reference only, no stats - All non-smoking tests

Table 6
Results of the Maximal Anaerobic Capacity (Wingate) Test for Leg
Exercise (mean \pm SD)

| | Non-Smokers (n = 20) | Smokers Non-Smoking (n = 12) | Smokers Smoking (n = 11) | Total Group (n = 32) |
|---------------|--------------------------------|--|--|--|
| COHb (pre) | ----- | 1.4 \pm 0.5 | 6.9 \pm 1.4 [†] | ----- |
| Max Power | 618 \pm 106 | 584 \pm 96 | 590 \pm 69 | 607 \pm 103 |
| Max Power/kg | 10.3 \pm 1.7 | 10.2 \pm 1.1 | 9.8 \pm 1.1 | 10.2 \pm 1.5 |
| Min Power | 280 \pm 55 | 261 \pm 46 | 264 \pm 51 | 275 \pm 53 |
| Min Power/kg | 4.7 \pm 1.0 | 4.5 \pm 0.7 | 4.4 \pm 1.0 | 4.7 \pm 0.9 |
| Mean Power | 413 \pm 60 | 374 \pm 49 | 383 \pm 45 | 401 \pm 59 |
| Mean Power/kg | 6.8 \pm 1.1 | 6.5 \pm 0.7 | 6.4 \pm 0.9 | 6.7 \pm 1. |
| % Fatigue | 54% \pm 10% | 55% \pm 8% | 54% \pm 11% | 54% \pm 10% |
| Max HR | 175 \pm 12 | 170 \pm 7 | 178 \pm 10 | 176 \pm 11 |
| Max LT | 8.6 \pm 2.0 | 8.7 \pm 1.5 | 7.4 \pm 1.4 | 8.6 \pm 1.8 |

* p \leq 0.05 , 2 tailed, independent *t*-test, Non-smokers vs Smokers (non-smoking days)

[†] p \leq 0.05 , 2 tailed, independent *t*-test, Smokers (non-smoking) vs Smokers (smoking) Tests

** For reference only, no stats - All non-smoking tests

Table 7
Results of the Maximal Anaerobic Capacity (Wingate) Test for Arm
Exercise (mean \pm SD)

| | Non-Smokers (n = 20) | Smokers Non-Smoking (n = 12) | Smokers Smoking (n = 11) | Total Group (n = 32) |
|---------------|--------------------------------|--|--|--|
| COHb (pre) | ----- | 1.5 \pm 0.6 | 6.4 \pm 1.1 [†] | ----- |
| Max Power | 323 \pm 55 | 327 \pm 36 | 302 \pm 27 [†] | 324 \pm 48 |
| Max Power/kg | 5.4 \pm 0.6 | 5.4 \pm 0.4 | 5.0 \pm 0.5 | 5.4 \pm 0.5 |
| Min Power | 162 \pm 34 | 151 \pm 31 | 148 \pm 27 | 158 \pm 32 |
| Min Power/kg | 2.7 \pm 0.6 | 2.6 \pm 0.4 | 2.5 \pm 0.5 | 2.7 \pm 0.8 |
| Mean Power | 228 \pm 38 | 226 \pm 21 | 209 \pm 23 | 227 \pm 33 |
| Mean Power/kg | 3.8 \pm 0.6 | 3.7 \pm 0.3 | 3.5 \pm 0.4 | 3.8 \pm 0.5 |
| % Fatigue | 49% \pm 10% | 51% \pm 11% | 50.9% \pm 9% | 50% \pm 10% |
| Max HR | 173 \pm 13 | 178 \pm 7 | 178 \pm 10 | 175 \pm 11 |
| Max LT | 6.9 \pm 1.5 | 7.3 \pm 1.7 | 7.6 \pm 2.2 | 7.1 \pm 1.6 |

* $p \leq 0.05$, 2 tailed, independent *t*-test, Non-smokers vs Smokers (non-smoking days)

[†] $p \leq 0.05$, 2 tailed, independent *t*-test, Smokers (non-smoking) vs Smokers (smoking) Tests

** For reference only, no stats - All non-smoking tests

Table 8

Correlations between Maximal Aerobic and Anaerobic Capacity

| | VO₂ Arm | Wingate Mean Power Leg | Wingate Mean Power Arm |
|-----------------------|-------------------------------|---------------------------------------|---------------------------------------|
| VO ₂ , Leg | 0.62** | 0.51** | 0.45* |
| VO ₂ , Arm | | 0.33 | 0.31 |
| Mean Power, Leg | 0.33 | 0.73** | |
| Mean Power, Arm | 0.31 | | |

* correlation (r) is significant at the 0.05 level (2-tailed)

** correlation (r) is significant at the 0.01 level (2-tailed)

Table 9
Correlations between the Army Physical Fitness Test
and Aerobic and Anaerobic Capacity

| | VO_{2max} Leg | VO_{2max} Arm | Wingate Leg Mean Power | Wingate Arm Mean Power |
|-----------------|----------------------------------|----------------------------------|-----------------------------------|-----------------------------------|
| 2 mile run time | -0.02 | -0.05 | -0.26 | -0.36 |
| Push Ups | 0.37 | 0.33 | 0.03 | 0.42 |
| Sit Ups | 0.62* | 0.34 | 0.37 | 0.61* |
| Total Score | 0.42* | 0.27 | 0.25 | 0.28 |

* correlation (r) is significant at the 0.05 level (2-tailed)

** correlation (r) is significant at the 0.01 level (2-tailed)

Table 10

**Comparison of Cardiopulmonary Variables at Maximal Leg Exercise in
Female Soldiers (pooled data) with Historical Values obtained in our
Laboratory in Male Soldiers (mean \pm SEM)**

| | Men¹ | Women | % Difference |
|---------------------------------|------------------------|------------------|---------------------|
| | (n = 16) | (n = 34) | Women vs Men |
| Power (W) | 253 \pm 10 | 164 \pm 4* | 65% |
| VO ₂ (L/min) | 3.26 \pm 0.14 | 1.95 \pm 0.05* | 60% |
| VO ₂ /kg (ml/kg/min) | 45.3 \pm 1.3 | 32.7 \pm 0.9* | 72% |
| V _E (L/min) | 144 \pm 8 | 90 \pm 3* | 63% |
| HR | 189 \pm 3 | 181 \pm 2 | 96% |

¹Chest 99: 420-425, 1991.

Table 11

**Comparison of Cardiopulmonary Variables at Maximal Arm Crank
Exercise in Female Soldiers (pooled data) with Historical Values
obtained in our Laboratory in Male Soldiers (mean \pm SEM)**

| | Men¹ | Women | % Difference |
|---------------------------------|------------------------|------------------|---------------------|
| | (n = 19) | (n = 34) | Women vs Men |
| Power (W) | 129 \pm 2 | 87 \pm 14* | 67% |
| VO ₂ (L/min) | 2.17 \pm 0.04 | 1.40 \pm 0.04* | 65% |
| VO ₂ /kg (ml/kg/min) | 30.5 \pm 0.8 | 23.5 \pm 0.8* | 77% |
| V _E (L/min) | 101 \pm 2 | 67 \pm 3* | 66% |
| HR | 168 \pm 3 | 175 \pm 2 | 104% |

¹Chest 99: 420-425, 1991.

Figure 1. Comparison of Maximal Aerobic Capacity ($\text{VO}_{2\text{max}}$) between Female Smokers and Non-Smokers for Arm and Leg Exercise (mean + SEM)

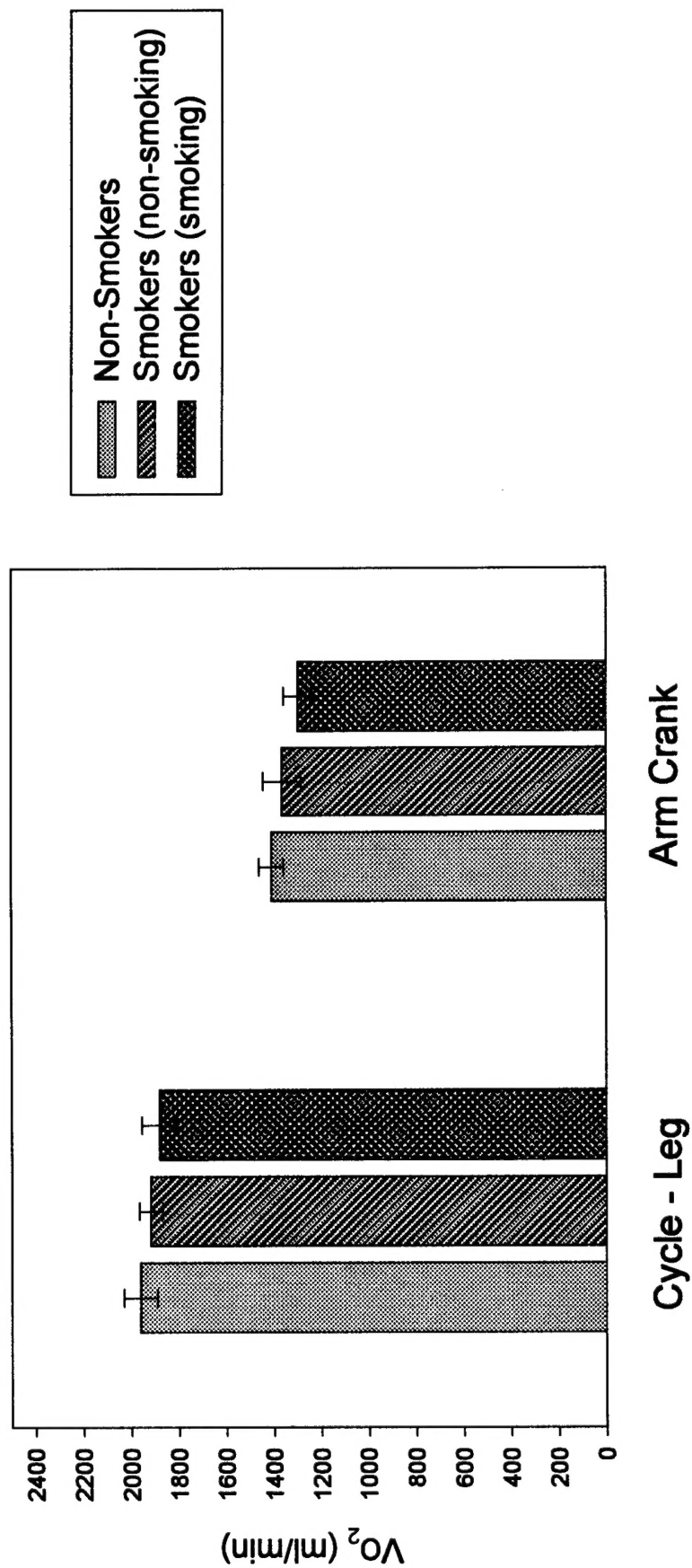


Figure 2. Comparison of Maximal Anaerobic Capacity (Wingate Test) between Female Smokers and Non-smokers for Arm and Leg Exercise (mean + SEM)

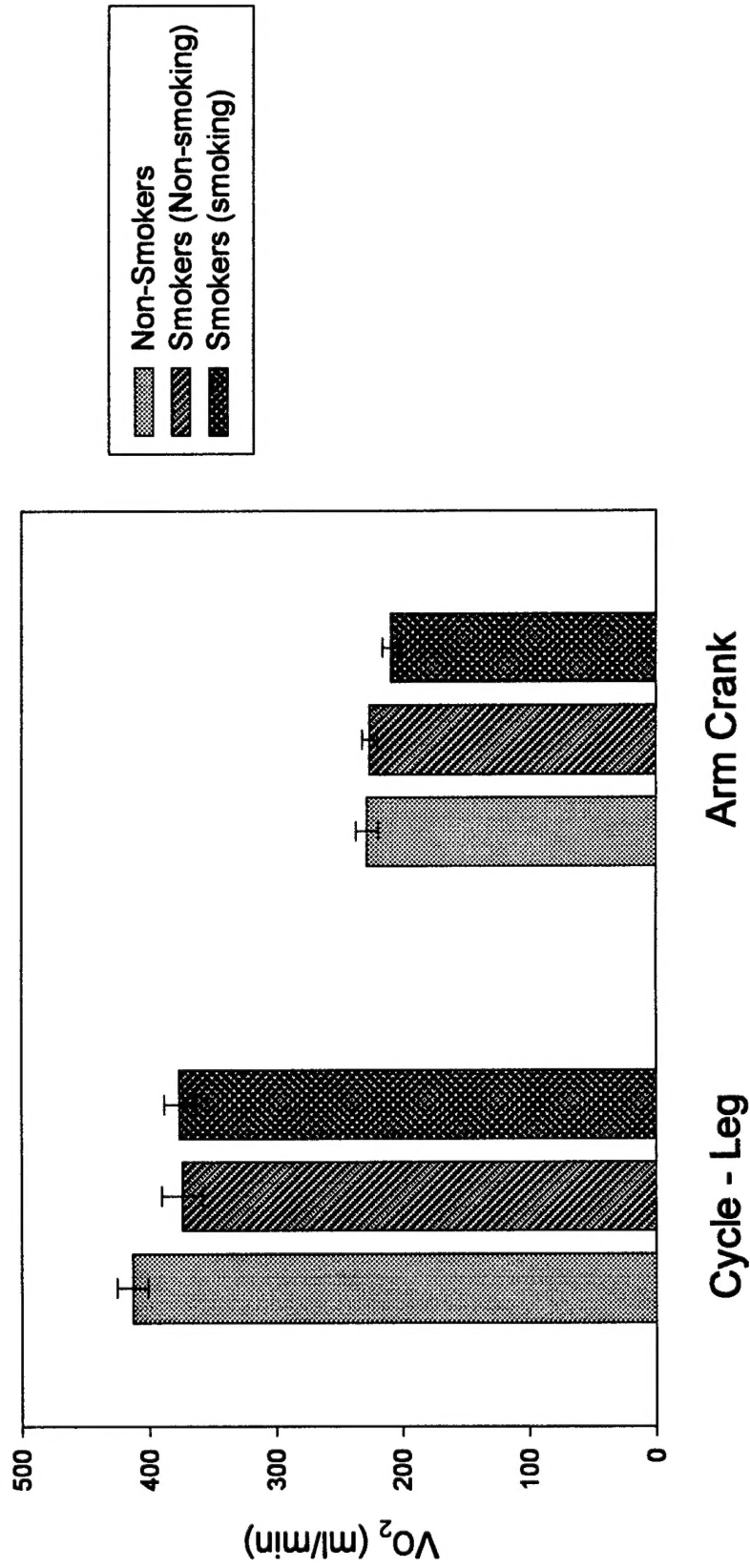
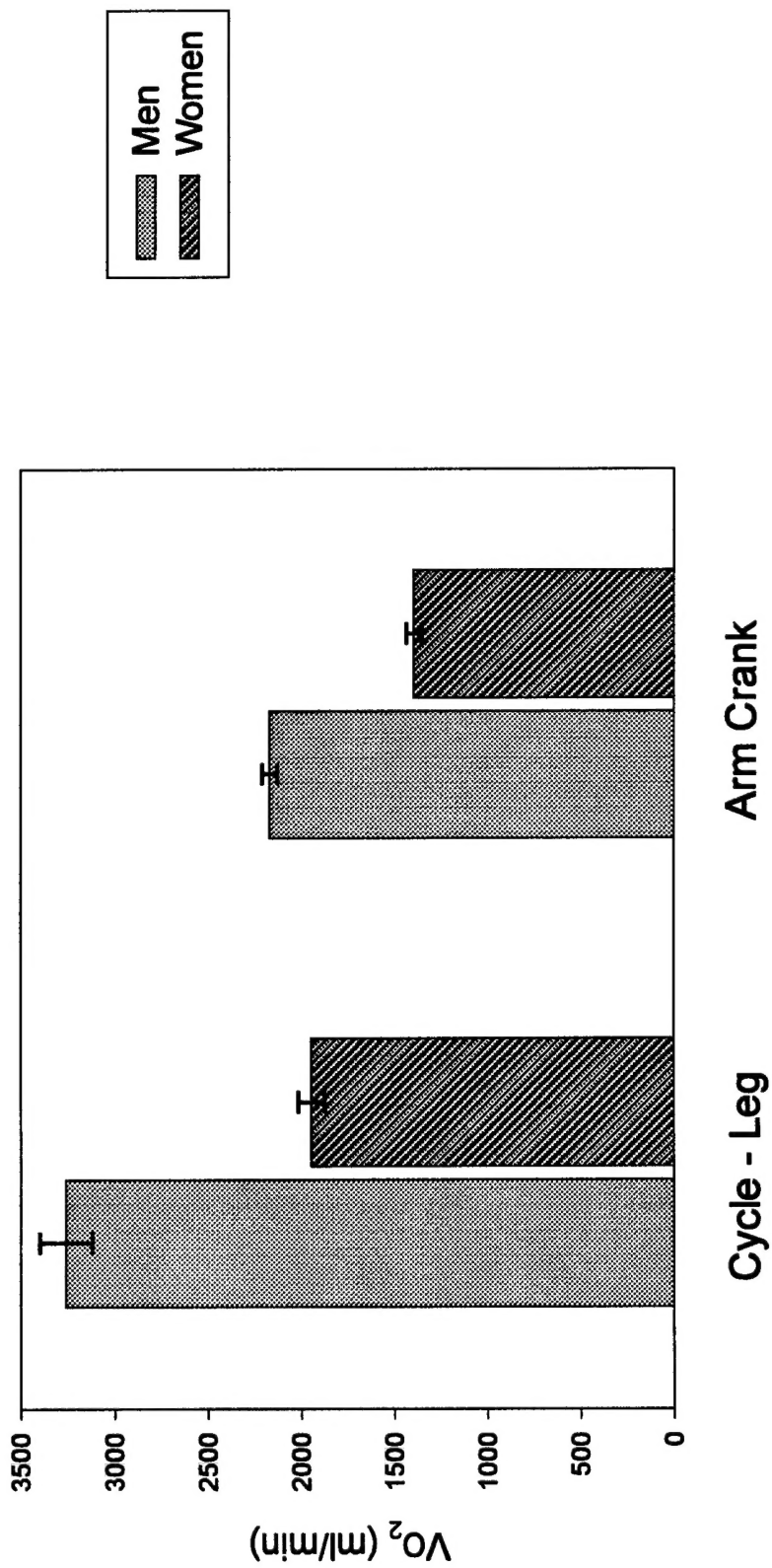


Figure 3. Comparison of Maximal Aerobic Capacity ($\text{VO}_{2\text{max}}$) between Male and Female Soldiers (mean \pm SEM)



SCIENTIFIC PRESENTATIONS

Connery SM, Zeballos RJ, Pusateri AE, Taylor MB, Weisman IM. $\Delta VO_2 / \Delta WR$ during cycle and arm crank ergometry in women.

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